REPORT FOR PERIOD ENDING JULY 31, 2000
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The Accelerated Climate Prediction Initiative (ACPI)

CAUTION/DISCLAIMER

The results given on this web site announce a new capability that will need to be exercised and refined many times before such results can be considered quantitatively reliable guides for policy makers and other potential users of this information. They represent ongoing, unpublished research that has not been vetted in formal scientific review and, therefore, should not be used as a guide to the future or referenced in any way. In the meantime, the results do raise a number of important issues and questions. It is important for policy makers and other users to know that such questions are being asked and now can be answered, albeit with unknown accuracy. Moreover, since we are dealing with long-term climate change, we expect the capability to do this kind of projection will improve significantly by the time it is necessary to use it. So the reader is advised that the results discussed, particularly in Element 3, are highly preliminary. We cannot, at this time, estimate their reliability and/or uncertainty. They are not for public or private use or dissemination to others.

The ACPI Pilot comprises three elements. Work on the first two elements began before July 2000 and is reported below. Within each element are several avenues of study headed by one or more Principal Investigators. The progress report is organized according to these elements and avenues of study. Additional information can be found on the SIO ACPI web sites http://meteora.ucsd.edu/~meyer/acpi_calif.html and http://goldhill.cgd.ucar.edu/pcm/ under ACPI Pilot Project, on the NCAR web site.

Element 1: Ocean Initial Conditions

Global Ocean Circulation Estimation (Stammer, SIO)

The Global Ocean Circulation Estimated from TOPEX/POSEIDON Altimetry and the MIT General Circulation Model
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July 9, 1997
See http://puddle.mit.edu/~detlef/OSE/global.html

In a first application we demonstrated the beginning of a global ocean circulation estimation system. A preliminary estimate was made of the global circulation as it emerges from constraining the MIT general circulation model by TOPEX/POSEIDON altimeter data from the year 1993. The model is forced to consistency with those data by using the models adjoint to modify the initial temperature and salinity fields over the full water column and to adjust the meteorological forcing fields for momentum, heat and fresh water. Results differ from either the model or the data alone, and describe a time-evolving state which --- based on the prescribed

error statistics --- appear to be consistent with: (1) the absolute T/P sea surface height relative to the EGM96 geoid model, (2) the time dependent T/P sea surface height component, (3) 10-day averages of NCEP surface fluxes of momentum, heat and fresh water, and (4) the annual mean theta, S climatology. From the present preliminary solution no obstacles are foreseen to obtain a more definitive solutions using all available observations, improved error statistics and improved model configurations.

A full report on the preliminary global state estimation is given at
http://puddle.mit.edu/~detlef/OSE/report_0/index.html .

Work in Progress (Tokmakian and Semtner, NPS)

Computations now underway are directed at greatly extending and improving the preliminary computation. Improvements include an increased model resolution to 1, an extended estimation period to 6 years (1992 through 1997), as well as more acurate representations of straits and sills in the topography. Equally important, a complete mixed layer model (Large et al., 1994) and an eddy parameterization (Gent and McWilliams, 1990) have been incorporated into the adjoint model. Moreover, a full (non-diagonal) geoid error covariance matrix is being used as well as other improvements in the remaining weights.

Data now include the absolute and time-varying T/P data from October 1992 through December 1997, SSH anomalies from the ERS-1 and ERS-2 satellites, monthly mean SST data (Reynolds and Smith, 1994), time-varying NCEP Re-Analysis fluxes of momentum, heat and freshwater, and NSCAT estimates of
wind stress errors are being employed. Monthly means of the model state are required to remain within assigned bounds of the monthly mean Levitus et al. (1994) climatology. Note that the control vector now contains 8 million elements and the costfunction has the form:

The set of computations now underway is still regarded as preliminary. The model resolution will eventually be greatly increased and as much as possible of the entire WOCE data set will be used. The combination of the OGCM with data, each appropriately weighted by its uncertainty estimates, should provide a useful basic description of the ocean circulation and its variability. Among many possible applications, one expects the production of much better estimates of property flux divergences, and the study of oceanic biogeochemical cycles which are dependent upon the circulation.

See http://puddle.mit.edu/~detlef/OSE/global.html for (1) a present status report of the ongoing global ocean state estimation over a 6-year period covering 1992 through 1997; (2) an animation of 6 years of model SSH anomaly fields obtained from 30th iteration (3) an animation of 6 years of estimated changes in NCEP net sea surface heat fluxes, which are required to bring the model into consistency with the data (4) an animation of 6 years of estimated changes in NCEP net sea surface fresh water fluxes, which are required to bring the model into consistency with the data.

Summary Of June 26 Breckenridge ACPI Pilot Meeting On Initialization

1. The NPG group reported that all the fields from Detlef Stammer's (DS) multi-year ocean data assimilation had been interpolated to the 2/3-degree POP grid of PCM 1.0 and made available

both as binary and netcdf files. Levitus data was also provided in the 2/3-degree grid. Ferret comparisons of DS and Levitus fields showed few differences below 500 m but warmer DS temperatures in about the range 100-300 m. Robin Tokmakian has run three 5-year POP simulations from DS initial conditions and DS forcing fields: run 1 was fully prognostic, run 2 added surface corrections to DS temperature and salinity, and run 3 was fully prognostic but used Gent-McWilliams (GM) closure with the variable coefficient method of Visbeck et al. tested by Craig et al. in prior 100-year POP runs. As indicated in a written handout and using various output from ferret analyses, the 2/3-degree POP runs showed strengthening and latitudinal shifting of major currents from the DS fields, but all the runs compared well with DS in terms of seasonal to interannual variations measured against tide gauges. Comparisons of changes in the global sea surface height showed POP's El Nino to be somewhat stronger than that of DS and for POP to be better matched to DS in midlatitudes when GM was used. Non-GM runs showed thermocline deepening to be occurring in the upper 1000 m.

2. At NCAR, Tony Craig did three 20-year runs with PCM 1.0 starting from the historical PCM atmosphere of 1991 and keeping CO2 and sulfates constant. Run 33 used May 1996 fields of DS simply as interpolated to the 2/3-degree POP grid, run 34 preconditioned the atmosphere first with six years of repeated 1996 SST from DS before fully coupled mode, and run 35 initialized the ocean with Robin's run #2 described above. Analyses of run 34 showed a significant upper ocean cooling (about 1.5 C in the range 25-100 m) and lower thermocline warming (about 0.5 C and continuing to rise at 1000 m). False thermocline deepening due to simple biharmonic mixing seems to be the cause of these changes, since total heat content of the ocean is only 0.01 C changed in the 20 years of run 34. Based on earlier tests with GM in the 2/3-degree POP using NCEP forcing, the false deepening could be arrested throughout most of the ocean basins by using this parameterization (although the N. Atlantic may become rather cold due to sensitivity to other thermohaline processes).

3. The SIO group had done some preliminary evaluations of the DS fields and examined how they projected onto existing PCM 1.0 historical runs and 21st Century simulations with rising CO2. The DS fields were fairly consistent with PCM results, although not entirely so; and the SIO group will continue to evaluate the use of the broad-scale fields below 200 m depth for use in initializing and running PCM simulations following their "anomaly coupling" strategy outlined at the La Jolla meeting.

4. At LANL, Mat Maltrud had run an identical DS resolution and forcing case with POP to compare against the DS simulation. Significant differences were found, only part of which may be due to an error in scaling the salinity forcing term. Further investigations are underway to understand differences that may be due to different numerical treatments of grid staggering. Because of the exhaustive comparisons that have been made of POP and NCOM, it is very unlikely that any fundamental problems exist in the POP formulation.

Following extensive discussion of the various results above, the group decided to continue their work as follows:

1. The NPS group will undertake a simulation with the 2/3 grid and multi-decadal forcing as an alternative method to initialize shorter-term climate variations that can be evaluated against the subsequent climate record. This would be compared against the DS assimilation results where altimeter and radiometer data have been used to estimate thermocline heat content over a shorter time period. If the results are promising, they can be tested in a PCM run similar to the ones done earlier at NCAR. The existing run 2 from NPS can provide initial conditions for new PCM 1.0

runs having the atmospheric model preconditioned by DS 1992-97 surface temperatures and running 20 years with and without flux adjustment.

2. The NCAR group will continue to make its existing simulation results available to the impact assessment studies funded by the ACPI-pilot effort; and NCAR will continue to evaluate PCM 1.0 levels of natural variability as well as the CO2-induced changes indicated by their ensemble of results for the year 2050. Since it is impractical to embed GM physics in the POP model used in PCM 1.0, Tony Craig will continue to develop and test version 2.0 of PCM with GM as well as KPP vertical mixing. The new model version can be used when ready to conduct simulations of CO2-induced change without the false thermocline deepening and likely reduction in CO2-induced response that may occur in the original PCM 1.0. The ACPI-pilot project may in fact provide a powerful motivation for constructing and using PCM 2.0.

3. The SIO group will pursue their anomaly coupling strategy and examine the shock to the climate system from various groups' approaches. They will be using the full PCM 1.O and running on the San Diego machines. Flux adjustments will be explored in this context. It is likely the best simulations will require some type of flux adjustment.

4. The LANL group will further explore the differences between POP results and DS fields. They will also examine the effects of introducing GM and KPP at the resolution used in DS, as was earlier discussed in La Jolla. Some LANL attention will be paid to the development of an adjoint version of POP that could be used for data assimilation; however, the expectation is that Detlef Stammer's effort will move to higher resolution, longer assimilations, better physics, and use of subsurface data, thus providing continuing upgrades to the initial conditions for a full-scale ACPI in future years.

Finally, it was agreed that the groups will try to share their ongoing results in a timely fashion by frequent communication, including the posting of ongoing analysis results on web pages. A meeting to evaluate progress and make further plans may be needed in the November time frame with a likely site of NCAR.

Element 2: Modeling Anthropogenic Climate Change

PCM (Washington, NCAR)

Progress Report - 5 July 2000

The observed ocean data from the first element of the ACPI Demonstration Project has been used to initialize the DOE supported Parallel Climate Model (PCM) for simulations of anthropogenic climate change.

Details of the PCM version 1 may be found at http://www.cgd.ucar.edu/pcm. The PCM has been developed with substantial distributed involvement of both government laboratories and universities. The NCAR/UCAR NSF supported Community Climate System Model (CCSM) is working closely with the PCM community to develop new generation climate models. The atmospheric component of the PCM is the CCM3 atmospheric general circulation model (AGCM) developed at NCAR and is used at T42 resolution (about 280 by 280 km grid). The

CCM3 includes a land surface model that accounts for soil moisture, vegetation types, etc, as well as an implied river transport model. The ocean component of PCM is the Parallel Ocean Program (POP) model developed jointly by LANL, Naval Postgraduate School (NPS) and NCAR. The final major model component of PCM is a sea ice model developed at NPS by Y. Zhang. The full PCM has been configured to run with a serial flux coupler that has been designed to perform the calculation of the components of the climate system as efficiently as possible on a variety of parallel high capacity supercomputers.

The PCM version 1 is currently fully operational. Analyses of ongoing simulations have shown realistic amplitude El Niño, La Niña, North Atlantic Oscillation (NAO), and Antarctic Circumpolar Wave properties in the simulations.

Three climate change simulations have been performed. The first uses the D. Stammer data for April 1996 as an initial condition. Note that the data was for a two-degree horizontal resolution MIT ocean model that has assimilated observed ocean data. The second simulation was the same as the first but with Newtonian forcing of the top layer temperature and salinity fields in the ocean model. The annual cycle of forcing was repeated for 5 years before being used in the PCM simulation. The final simulation first uses the D. Stammer data in an uncoupled PCM 2/3-degree ocean model in a spin up phase. The initial data used in the spin up of the stand alone ocean started in 1992 and the top layer temperature and salinity were forced by Newtonian forcing using the Stammer observed data from 1992 to 1996. The results from the first two simulations showed that starting from the two-degree Stammer data gave a very smooth initial ocean current systems and that there was a great deal of initial shock to the system. As the simulation proceeded the kinetic energy nearly doubled as the 2/3-degree ocean model allowed for some eddy activity and the currents became stronger. It was generally agreed that the simulations did not give realistic simulations but did establish a baseline. The third simulation with a "spun up" ocean at the 2/3-degree resolution gave a more reasonable simulation but with ocean biases. Some of the model biases will be removed with an improved boundary layer parameterization and the improved treatment of isopycnal mixing along constant density layers. We will repeat these simulations with version 2 of PCM. PCM version 2 includes the new ocean physics, which will decrease the biases within the thermocline.

We have also generated some special data sets for the regional climate modeling and impacts community that are involved in the ACPI demonstration project. The simulated data is for two periods, the first is for the present climate period (1975-1995) and the second is for a future climate (2030-2050). The interval between files is 6 hours. The specific variables that will be made available to the regional model community have been worked out in detail. A web based data archive will be established at PCMDI/NERSC, which will allow easy access by users.